DEVICES FOR MANAGING HOUSING EXPANSION IN EXHAUST EMISSION CONTROL DEVICES

RELATED APPLICATION

[0001]This disclosure claims the benefit of commonly owned and assigned United States Patent provisional application serial number 60/289,682, filed on May 9, 2001, the contents of which are incorporated herein by reference.

TECHNICAL FIELD

[0002]This disclosure relates to devices for managing housing expansion in exhaust emission control devices.

BACKGROUND OF THE INVENTION

[0003]Pollution or exhaust emission control devices are employed on motor vehicles to control atmospheric pollution. Two types of devices are currently in widespread use--catalytic converters and diesel particulate filters or traps. Catalytic converters contain a catalyst, which is typically coated on a catalytic element or substrate which is usually a monolithic structure mounted in the converter. The monolithic structures are typically ceramic, although metal monoliths and foils have been used. The catalyst oxidizes carbon monoxide and hydrocarbons, and reduces the oxides of nitrogen in automobile exhaust gases to control atmospheric pollution. Diesel particulate filters or traps are wall flow filters which have honeycombed monolithic structures typically made from porous crystalline ceramic materials. Usually these devices have a metal housing which holds within it a monolithic structure or element that is most commonly ceramic. The ceramic monolith generally has very thin walls to provide a large amount of surface area and is fragile and susceptible to breakage. To avoid damage to the ceramic monolith from road shock and vibration, to compensate for thermal expansion differences, and to prevent exhaust gases from passing between the monolith and metal housing rather than through the monolith ceramic, a gasket, generally a retention mat or paste material is typically disposed between the ceramic

monolith and the metal housing. This can conveniently be accomplished by wrapping a sheet or retention mat material around the monolith and inserting the wrapped monolith into the housing. It is evident that these devices are subjected to the relatively high temperatures inherent in engine exhaust.

[0004] In the past, most of these exhaust emission control devices have used a monolithic cordierite substrate with a cellular structure to provide a high surface area on which a catalyst coating is applied, and/or filtered through. In the case of diesel particulate traps, alternate cells on the inlet and outlet ends are usually plugged. This forces the exhaust gases to flow through the porous walls, which filters out the small soot particles. A diesel particulate trap substrate made from Silicon Carbide (SiC) has recently been developed. SiC material is used due to its improved resistance to failure during high temperature soot burn out, for its more uniform pore size, and for better filtration, than traps made from cordierite. Accordingly it is advantageous to employ such silicon carbide substrates.

[0005] Additionally, in a typical operation a diesel particulate trap accumulates soot for a period of time, while operating at lower temperatures of about 300 degrees C. If a high load condition is encountered when the trap is loaded with soot, the engines' computer calibration system will cause an increase in exhaust gas temperature, to about 600 degrees C by some means such as reducing the intake airflow. Once the desired temperature is reached in the trap the soot starts burning, and then generates enough heat so the burn continues even if the exhaust temperature drops. This allows the engine calibration to be returned to normal as soon as the burn has started. This soot burning cycle is referred to as "regeneration" and causes relatively large temperature differentials, in the emission control devices.

[0006] While the state of the art emission control device materials and methods have their own utilities and advantages, there remains an ongoing need to improve materials in emission devices especially for use with silicon carbide substrates. It would be particularly desirable to provide materials and device geometry that function well over broad temperature ranges and preferably by using economical materials.

[0007]The difficulty is particularly acute because the internal element is exposed directly to the high temperatures of the exhaust gas while the outer shell is frequently insulated from these high temperatures by the retention mat. If the expansion of the monolith is sufficiently different from that of the housing this will cause excess pressure on the relatively fragile element and may also cause irreversible deformation of the retention mat or gasket.

[0008]It is desirable to minimize or substantially eliminate the effect of these temperature differentials.

[0009]It has now been recognized that the coefficient of expansion of a silicon carbide (SiC) element or substrate is about four times greater than that of the usual cordierite substrate. When using a SiC diesel particulate substrate the expansion of the substrate may cause crushing of the mat retention materials, which are placed between the substrate and the housing, for retention of the substrate in the housing and for sealing the periphery of the substrate to direct the exhaust through the monolith.

[0010]The coefficient of expansion of the SiC monolith or substrate is a relatively high 4×10^{-6}, whereas the usual cordierite substrate has a coefficient of expansion of about 1×10^{-6}. The housing or canister, if made up of SAE 409 type steel has a coefficient of expansion of about 11.7×10^{-6}. Even though the coefficient of expansion of the housing is greater than that of the SiC substrate, the direct contact of the substrate with the exhaust gases heats it to a much higher temperature than the housing, causing it to expand more than the housing. This is especially true for the high temperatures encountered during regeneration.

[0011]The differential expansion of the substrate and the housing causes excess pressure on the retention mats which in turn can crush the mats. Depending on the material from which the mats are made this crushing or excess deformation may be permanent and thus leave a gap between the substrate and the mat. In the normal use of the auto emission devices the inherent vibrations as well as thermal differentials require a relatively rigid construction and if the gaps remaining are sufficiently large it is possible to

damage the substrate by vibration as well as allowing gas to by pass the substrate. An objective of this invention is to at least partially control or manage the expansion of the housing to match that of the substrate.

SUMMARY

[0012]By managing or controlling this expansion, the retention mat usually employed can be maintained in good condition to avoid vibrational or other damage to the substrate. This can be accomplished in a number of ways. In one embodiment an emission control device of the type comprising a permeable silicon-carbide substrate contained within a metallic housing is disclosed with sufficient clearance between the housing and the substrate to permit the thermal expansion of the substrate within the housing when the device is heated from ambient to operating temperature, the substrate being positioned within the housing and in use the gas being directed through the substrate by an intumescent gasket. The improvement comprising: the metal of the metallic housing having a coefficient of thermal expansion equal to or greater than 18×10^{-6} centimeter per degree Celsius, the improvement providing reduced frequency of substrate failure and wear on the gasket in use.

[0013]In a second embodiment a gasket is particularly adapted to inhibit the flow of gas in a space formed by adjacent parallel walls while simultaneously permitting an exchange of thermal energy between the gas and at least one of the walls, comprising: a member which in use inhibits the flow of the gas the member having at least one channel sufficient to permit access of the gas in sufficient proximity to the surface of the wall for a portion of an interface between the member and the wall to permit exchange of thermal energy between a gas contained within the channel and the wall.

[0014]In another embodiment, a gasket is particularly adapted to inhibit the flow of a gas in a space formed by a permeable silicon-carbide substrate mounted within a metallic housing in a catalytic converter device while simultaneously permitting exchange of thermal energy between the gas and the metallic housing, comprising: an intumescent gas impermeable member comprising mica ceramic fiber having at least one channel that permits fluid

communication of the gas with the housing for a portion of the surface of the interface of the member and the housing.

[0015]In yet another embodiment, an emission control device, is disclosed comprising: a treatment element comprising a silicon-carbide substrate, contained within a metallic housing to permit expansion of the treatment element when the emission control device is heated to an operating temperature; and ports in the housing to provide for inlet and exhaust of a gas; the treatment element being positioned and affixed within the housing by a gasket being particularly adapted to simultaneously inhibit the flow of gas in a space defined by the treatment element and the housing between the ports in the housing while permitting the exchange of thermal energy between the gas and at least one of the housing and the treatment element by at least one channel in the gasket to permit access of the gas in proximity of the housing or the treatment element for a portion of the interface between the gasket and the housing or the treatment element.

[0016]In another embodiment an emission control device housing is disclosed comprising: nested metallic housings comprising an inner housing and an outer housing, the nested metallic housings both having input ports and exhaust ports, the inner housing being configured with the outer housing to form at least one channel between the inner housing and the outer housing to: permit the exchange of thermal energy between at least a portion of a gas flowing from the input port to the exhaust port of the outer housing; and limit the flow of the gas through the device through the input port of the inner housing.

[0017]In another embodiment, an emission control device canister is disclosed comprising: nested metallic housings comprising an outer housing having inlet means and outlet means for a gas stream to be treated; and an inner housing connected to at least a portion of the outer housing to form a channel between the outer and inner housings, the connection sealing off the gas path of the outer housing to prevent free passage from the inlet means to the outlet means to ensure that at least a portion of gas flows into the channel and

that substantially all of the gas flows through the inner housing to permit an exchange of thermal energy between the gas and the housings.

[0018]In another embodiment, an emission control device housing is disclosed for an exhaust gas having thermal energy comprising: an outer metallic housing having gas flow inlet means and outlet means; an inner metallic liner for the housing being attached to at least a portion of the outer housing so as to form a channel between the housing and the liner, the channel being open on at least one end; the attachment being gas impermeable to direct the flow at least a portion of the gas to the channel and to the inner metallic liner to permit exchange of at least a portion of the thermal energy contained in the gas with the housing and the liner.

[0019]In another embodiment, an emission control device is disclosed, comprising: nested metallic housings comprising an inner housing and an outer housing, the nested metallic housings both having input ports and output ports, the inner housing configured with the outer housing to form at least one channel between the inner housing and the outer housing to: permit the exchange of thermal energy between at least a portion of a gas flowing from the input port to the exhaust port of the outer housing; and limit the flow of a gas through the device through the input port of the inner housing; a treatment element comprising a silicon-carbide substrate disposed within the inner housing; wherein the treatment element is affixed within the inner housing by a gasket, which gasket is sufficient to inhibit the flow of a gas around the substrate and to prevent the substrate from contacting the housings.

[0020]The embodiments described above used either alone or in combination serve to manage the thermal expansion of the housing of the device to reduce or substantially eliminate excessive crushing of the retention mat which improves the life of the mat and reduces the frequency of substrate failure.

BRIEF DISCRIPTION OF THE DRAWINGS

[0021]Referring now to the figures, where like elements are numbered alike:

[0022]Figure 1 is a partially cut-away perspective view of an exhaust emission control device;

[0023]Figure 2 is a cross-sectional view of the exhaust emission control device of Figure 1, taken along lines 2-2;

[0024]Figure 3 is a graph of the resulting retention pressure provided by a first gasket during a Real Condition Fixture Test;

[0025]Figure 4 is a graph of the resulting retention pressure provided by a second gasket during a Real Condition Fixture Test;

[0026]Figure 5 is cross-sectional view of an exemplary embodiment of an exhaust emission control device taken along the flow of the exhaust gas;

[0027]Figure 6 is cross-sectional view of an alternate embodiment of the exhaust emission control device of Figure 5;

[0028]Figure 7 is a partially cut-away perspective view of an exhaust emission control device;

[0029]Figure 8 is a top view of an exemplary embodiment of a gasket used in the exhaust emission control device of Figure 7;

[0030]Figure 9 is a top view of an alternate exemplary embodiment of the gasket of Figure 8;

[0031]Figure 10 is a top view of another alternate exemplary embodiment of the gasket of Figure 8; and

[0032]Figure 11 is a cross-sectional view of an alternate exemplary embodiment of an exhaust emission control device taken along the flow of the exhaust gas.

DESCRIPTION OF THE INVENTION

[0033]In order to clarify the improvement herein a typical prior art device will be described in Figures 1 and 2.

[0034]Figures 1 and 2 illustrate a typical exhaust emission control device 10 which includes an outer metallic housing 12, a treatment element or monolithic substrate 14, and a retention mat or gasket 16. The treatment element converts, and/or eliminates one or more emissions from an

exhaust gas. In the example where the device 10 is a diesel particulate trap, the treatment element 14 is preferably a permeable silicon carbide substrate. The treatment element has a cellular or honeycomb structure that includes a plurality of cells 18 which provide passages for the exhaust gas and increase the surface area of the treatment element. As mentioned above, in diesel particulate traps alternate cells on the inlet and outlet ends are plugged to ensure that the gas passes through the walls of the element.

[0035]The retention mat or gasket 16 provides a pressure on the treatment element 14 by filling the space 20 between the treatment element and the housing 12. Moreover, the gasket 16 seals the space 20 between the treatment element and the housing 12 to ensure that the exhaust gas passes through, and not around, the cells 18 of the treatment element.

[0036]In use, the device 10 is subjected to a large range of temperatures and vibrations. Accordingly, the pressure placed on the treatment element or substrate by the gasket 16 must be sufficient to successfully hold the treatment element in the housing and insulate it from shock and vibration as well as to ensure that the exhaust gas passes through the cells 18 of the treatment element.

[0037]The choice of material for the housing 12 depends upon the type of exhaust gas, the maximum temperature reached by the device 10, the maximum temperature of the exhaust gas stream, and the like. In the past, suitable materials included any material capable of resisting under-car salt, temperature, and corrosion. Typically, ferrous materials were employed such as ferritic stainless steels. Ferritic stainless steels include stainless steels such as, e.g., the 400 – Series such as SS-409, SS-439, and SS-441.

[0038]The emission control device is subjected to a large range of temperatures. For example, in colder climates, the device is exposed to temperatures as low as about -40 degrees C (Celsius) when at rest, to over about 1000 degrees C when in use. Moreover, the device is exposed to repeated cyclic action between high and low temperatures many times over its useful life due to its normal operation and/or during regeneration of the device.

[0039]Commonly, in the diesel particulate traps the treatment element 14 is formed of a gas permeable silicon-carbide (SiC) substrate. As mentioned above, the SiC materials of the treatment element 14 are resistant to failure during use and during regeneration. These materials have a coefficient of thermal expansion of about 4 x 10^{-6} cm (centimeter) per degree C in the normal operating temperature range of the device. Prior art housings have commonly been formed of "ferritic steels" such as SAE 409 type stainless steel, which has a coefficient of thermal expansion of about 12 x 10^{-6} cm per degree C in the normal operating temperature range of the device. The difference in the thermal expansion coefficient between the housing and the treatment element is sufficient that the outer housing 12 would be expected to expand more than treatment element 14. However, this is often not the case since the expansion is due not only to the thermal expansion coefficient, but also to the temperatures reached by the housing and the treatment element which temperatures can be significantly different.

[0040]The treatment element often expands more than the housing where the treatment element has a higher operating temperature than the housing. The higher temperature is due to several factors. The retention mat or gasket 16 usually employed has insulating properties, which insulate the housing from some of the heat of the exhaust gas. Thus, heat from the exhaust gas in the substrate or treatment element is not fully transferred to the housing due to the insulating effect of the gasket. Additionally, the external portion of the housing is exposed to ambient air which dissipates the heat from the housing. Accordingly, the housing of the art is usually exposed to a lower temperature than the treatment element 14, which can counteract the differences in their coefficients of thermal expansion.

[0041]The reliability of the overall device is compromised when the coefficient of thermal expansion of the housing is sufficiently close to that of the treatment element under conditions where the housing is exposed to significantly less heat than the treatment element. Under these conditions, the lower temperature of the housing produces a lower rate of expansion for the housing than for the treatment element. This reduces the space between the

housing and the treatment element. This reduction in the space 20 between the housing 12 and the treatment element 14 compresses the gasket and/or increases the pressure on treatment element. The treatment element and/or the gasket often have fragile components that are prone to damage by pressures above a predetermined limit.

[0042]Commercially available gaskets formed of intumescent materials (e.g., materials that expand when heated) further increase the pressure on the treatment element. Use of gaskets formed of intumescent materials is desirable because they are of significantly lower cost than other available gaskets (e.g., non- intumescent gaskets). However, such less expensive intumescent gaskets tend to increase the damage (e.g., crushing) to the treatment element, which often leads to failure of device. Additionally, the intumescent gaskets are themselves fragile, and thus prone to losing the ability to provide sufficient pressure on the treatment element 14 over time as a result of being crushed by the reduction in the space 20. Thus, prior devices have required the use of more expensive, non-intumescent gaskets

[0043]Figures 3-4 are provided to further illustrate crushing of the retention gaskets. These Figures illustrate results of testing an emission control device in a Real Condition Fixture Test apparatus (RCFT) such as those available from The Minnesota, Mining and Manufacturing Company this RCFT apparatus is described in U.S. Patent 5,853,675. The RCFT apparatus is controlled to cycle the device 10 from an ambient temperature to a predetermined operating temperature (i.e., ramp-up), to hold the device at the predetermined operating temperature for a period of time (i.e., soak), and then to return the device to the ambient temperature (i.e., ramp-down). The RCFT apparatus is set up to measure the pressure exerted on the treatment element 14, the temperature of the treatment element, the temperature of the housing 12, and the resulting change in the space 20 during each cycle.

[0044]Figures 3 and 4 illustrate the temperature difference of the housing and the treatment element during several cycles of the RCFT apparatus. In Figures 3 and 4 along the axis entitled temperature, the temperature of the housing 12 and the treatment element 14, taken at

simultaneous points, is illustrated. In Figure 3, the maximum temperature reached by the housing is 530 degrees C (Celsius), while the maximum temperature reached by the treatment element is 800 degrees C. Similarly in Figure 4, the maximum temperature of the housing is 550 degrees C, while the maximum temperature of the treatment element is 800 degrees C. Under these conditions, the lower temperature of the housing as compared to the treatment element produces a lower rate of expansion for the housing than for the treatment element, which reduces the space 20 between the housing and the treatment element.

[0045] Figures 3 and 4 also illustrate the effect the reduction in the space between the housing and the treatment element has on the pressure exerted on the treatment element. Both Figures 3 and 4 illustrate results of three cycles from the RCFT apparatus on a silicon-carbide treatment element secured in a ferritic steel housing. In Figure 3, the treatment element is sealed in the housing by an intumescent gasket 16, and in Figure 4 the treatment element is sealed in the housing by a non-intumescent gasket. In both examples, the treatment element initially expands at a faster rate than the housing. As discussed above, this is due to the coefficient of thermal expansion of the treatment element (4×10^{-6} cm per degree C) being close to that of the ferritic steel housing (12×10^{-6} cm per degree C), while the treatment element is exposed to a significantly higher temperature than the housing. This change in the space 20 damages the less expensive commercially available intumescent gaskets that do not have sufficient elasticity to rebound from the initial compression caused by the change in space 20, especially after repeated cycling.

[0046] As illustrated in Figure 3, the space 20 initially decreases by about –0.13 millimeters (mm), before increasing by about + 0.15 mm. In the first cycle, the initial decrease in the space 20, and the expansion of the intumescent gasket 16 results in an increase in the pressure on the treatment element from an initial pressure of about 160 kilopascals (kPa) to a maximum pressure of about 1300 kPa. This maximum pressure is often sufficient to damage or crush the treatment element 14. At the beginning of the second

cycle, the initial pressure is only about 20 kilopascals (kPa) due to the damage inflicted on the intumescent gasket 16 during the first cycle. At the beginning of the third cycle, the initial pressure is only about 10 kilopascals (kPa) again due to the damage inflicted on the intumescent gasket during the first and second cycles. These effects on the intumescent gasket lead to a loss of retention pressure on the treatment element and could lead eventually to failure of the device 10 after repeated cycling. The input used to calculate how the gap between the substrate and housing changes for the RCFT is determined by measuring the temperature of the substrate surface adjacent to the mat and the housing surface adjacent to the mat during a typical warm-up to operating temperature cycle of the diesel particulate trap. The temperature of the substrate is multiplied by the coefficient of expansion of the substrate material and the substrate diameter to obtain the growth of the substrate at various temperatures. Similarly the temperature of the housing is multiplied by the coefficient of expansion of the housing material, and the housing diameter to obtain growth of the housing at various temperatures.

[0047]In sum, use of an intumescent gasket 16 to seal the silicon carbide treatment element 14 in the ferritic steel housings 12 leads to a loss of the gasket's ability to firmly retain the treatment element in the housing and to seal the space 20. Additionally, use of an intumescent gasket 16 to seal the silicon carbide treatment element in the ferritic steel housing increases the pressure exerted on the treatment element by the gasket, which also often leads to failure of the device.

[0048]In contrast to the intumescent gasket 16 of Figure 3, Figure 4 illustrates a non-intumescent gasket sealing the silicon carbide treatment element in the ferritic steel housing. Here, the space 20 initially decreases by about –0.10 millimeters (mm), before increasing by about + 0.14 mm. In the first cycle, the pressure on the treatment element 14 declines from an initial pressure of about 180 kilopascals (kPa), to a minimum pressure of about 100 kPa due to the non-intumescent gasket 16. During the second cycle, the initial pressure is about 140 kilopascals (kPa) and it reduces to a minimum pressure of about 95 kPa. During the third cycle, the initial pressure is about

120 kilopascals (kPa) and it reduces to a minimum pressure of about 90 kPa. Use of non-intumescent gaskets is necessary to seal the silicon carbide treatment elements in the ferritic steel housings. However, such non-intumescent gaskets are more costly than the intumescent gaskets, and thus lead to an overall increase in the cost of the device 10.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0049]Referring now to Figures 5-11, exemplary embodiments of diesel particulate traps having housings and/or gaskets selected for use with a substrate preferably a silicon-carbide treatment element are provided. These exemplary embodiments of the diesel particulate traps enable the use of less expensive commercially available intumescent gaskets through management of expansion of the housing with respect to expansion of the treatment element. Here, similar elements are labeled in multiples of one hundred.

[0050]A cross section of an exemplary embodiment of an exhaust emission control device 110 is illustrated in Figure 5. The device 110 is a diesel particulate trap comprising an outer housing 112, a treatment element 114, a gasket 116, and an inner housing 122. In this embodiment, the inner housing 122 is nested within the outer housing 112 and a space 120 is formed between the inner housing and the treatment element 114. The gasket 116 seals the treatment element 114 in the space 120 when it is compressed to a density of at least about 0.8 g/cc (grams/cubic centimeter), more preferably about 1.0 g/cc.

[0051]The treatment element 114 includes a plurality of cells (not shown), which provide passages for the exhaust gas and increase the surface area of the treatment element. The size and geometry of the treatment element 114 are chosen to optimize surface area of the cells 118 in the given design parameters of the device 110. Typically, the treatment element 114 has honeycomb-like geometry. The cells 118 are contemplated as having any polygonal or rounded shape, with substantially square, triangular, pentagonal, hexagonal, heptagonal, or octagonal, or similar geometries, as well as combinations comprising at least one of these geometries, preferred, due to ease of manufacturing and increased surface area.

[0052]The treatment element 114 is preferably a permeable silicon-carbide substrate having a coefficient of thermal expansion of about 4 x 10^{-6} cm per degree C. The treatment element 114 is (1) capable of operating at temperatures up to about 1,000°C; (2) capable of withstanding exposure to hydrocarbons, nitrogen oxides, carbon monoxide, carbon dioxide, and/or sulfur; and if a catalyst is employed, (3) having sufficient surface area and structural integrity to reduce at least one component of the exhaust gas.

[0053]Depending upon the type of the device 110, disposed on and/or throughout the treatment element 114 may be a catalyst for converting one or more exhaust gasses (e.g., hydrocarbons, carbon monoxide, sulfur, nitrogen oxides, and the like) to acceptable emissions levels. The catalyst comprises one or more catalyst materials that are wash coated, imbibed, impregnated, physisorbed, chemisorbed, precipitated, or otherwise applied to treatment element 114. Possible catalyst materials include metals, such as platinum, palladium, rhodium, iridium, osmium, ruthenium, tantalum, zirconium, yttrium, cerium, nickel, copper, and the like, as well as oxides, alloys, and combinations comprising at least one of the foregoing catalyst materials, and other catalysts.

[0054]The gasket 116 provides pressure on the treatment element 114 by filling the space 120 between the treatment element and the housing 112. Moreover, the gasket 116 seals the space 120 between the treatment element 114 and the housing 112 to ensure that the exhaust gas passes through, and not around, the treatment element. The gasket 116, which is preferably concentrically disposed around the treatment element 114, comprises an intumescent material that expands with heating to maintain firm uniform compression, or selectively non-uniform compression, if desired, on the treatment element. The intumescent material comprises ceramic materials such as mica ceramic fiber, alkali metal silicates and expandable graphites and other materials such as organic binders and the like, or combinations comprising at least one of the foregoing materials, and a vermiculite component. Intumescent materials include materials, sold under the trademark "INTERAM" by the "3M" Company, Minneapolis, Minnesota, such as INTERAM 100, as well as those

intumescents which are also sold under the aforementioned "FIBERFRAX" trademark by the Unifrax Co., Niagara Falls, New York as well as combinations comprising at least one of the foregoing materials, and others.

[0055]A channel 124 is defined between the outer housing 112 and the inner housing 122. The channel has an input port 123 and an exhaust port 125. In this embodiment, the exhaust port 125 of the outer housing 112 is merged with the exhaust port 125 of the inner housing 122. Accordingly, the channel 124 permits the exchange of thermal energy between at least a portion of a gas flowing from the input port to the exhaust port of the outer housing 112. The channel 124 exposes the inner housing 122 to the heat within the exhaust gas by providing a path through the input ports 123 for the exhaust gas to pass around the periphery of the inner housing. Additionally, the channel 124 ensures that the exhaust gas does not bypass the treatment element 114 by having the exhaust port 125 of the outer housing 112 merged with the exhaust port 125 of the inner housing 122. In this manner, the device 110 minimizes the temperature difference between the inner housing 122 and the treatment element 114.

[0056]The reduction in the temperature difference between the inner housing 122 and the treatment element 114 mitigates the differences in the coefficient of thermal expansion between the inner housing and the treatment element 114. This in turn, reduces and/or eliminates the change in the space 120 caused by the heat in the exhaust gas. In this manner, the device reduces damage to the treatment element 114 by managing the expansion of the inner housing 122 with respect to the treatment element 114 to minimize changes to the space 120 enables the use of lower cost gaskets 116 and increases the useful life of the gasket.

[0057]It should be recognized that the inner housing 122 is described above by way of example as having the exhaust port 125 of the outer housing 112 merged with the exhaust port 125 of the inner housing 122. Of course other embodiments that enable the exchange of thermal energy between at least a portion of a gas flowing from the input port to the exhaust port of the outer housing 112 are contemplated. For example in one alternative

embodiment, the input port 123 of the outer housing 112 is merged with the input port 125 of the inner housing 122. In Figure 5 the inner housing 122 is attached to form a gas impermeable barrier to the outer housing 112 on the outlet side but it is also possible to achieve similar results if the inner housing 122 is attached or fixed to the outer housing 112 on the inlet side. In the first instance a portion of the exhaust gas circulates before it passes through the substrate. In the second case a portion of the exhaust gas circulates after it passes through the substrate. Additionally in another alternate embodiment illustrated in Figure 6, the inner housing 122 is joined to the outer housing 112 by a member 115 that inhibits the flow of gas between the input port 123 and the exhaust port 125 of the outer housing.

[0058]Referring now to Figures 7 and 8, an alternate embodiment of a treatment device 310 is illustrated. The device 310 includes a housing 312, a treatment element 314, and a gasket 316. The treatment element includes cells 318, which provide passages for the exhaust gas and increase the surface area of the treatment element. The gasket seals the treatment element in the housing by filling the space between the housing and the treatment element. The gasket seals the treatment element in the space when it is compressed to a density of at least about 0.8 g/cc (grams/cubic centimeter), more preferably about 1.0 g/cc.

[0059]The gasket 316 is particularly adapted to inhibit the flow of gas in the space 320 formed by the adjacent walls of the housing and the treatment element, while simultaneously permitting an exchange of thermal energy between the exhaust gas and at least one of the walls. More specifically, the gasket 316 includes a member 342 having at least one channel 340. The channels 340 are sufficient to permit access of a portion of the exhaust gas to at least the surface of housing 312, and/or to the surface of the treatment element 314. Thus, the channels 340 permit the exchange of thermal energy between the gas contained within the channel and the surface of housing 312 and/or the treatment element 314.

[0060]In use, the gasket is wrapped about the treatment element such that the channels 340 are open to either the inlet and outlet sides of the

treatment element. The channels are provided in the gasket between the housing 312 and the treatment element 314 such that the channels expose at least the housing to the heat within the exhaust gas by providing a path for the exhaust gas around a portion of the inner periphery of the housing. However, the member 342 acts also to seal the space 320 between the housing and the treatment element to ensure that the exhaust gas is diverted through the monolith. In this way, the channels 340 minimize the temperature difference between the housing 312 and the treatment element 314, while the member 342 seals the space 320 and retains the treatment element in the housing.

[0061]Minimizing the temperature difference between the housing and the treatment element by the geometry of the gasket substantially reduces the effect of the differences in the coefficient of thermal expansion between the housing and the treatment element. In this manner, the device increases the useful life of the gasket, and/or reduces damage to the treatment element by managing the expansion of the housing with respect to the treatment element to minimize changes to the space 320. Further it enables the use of lower cost intumescent gaskets.

[0062]Referring now to Figures 9 and 10, various alternate exemplary embodiments of the gasket 316 of Figure 7 are provided. Here, the gasket 316 is shown in an open state, prior to being wrapped about the treatment element 314. In use, the gasket is wrapped about the treatment element so that the channels 340 are open to both the inlet and outlet sides of the treatment element. As illustrated, the channels 340 are designed to expose a portion of the housing 312 to the flow of the exhaust gas. Additionally, the member 342 blocks the flow of the exhaust gas from flowing through the space 320 from the inlet to the outlet of the housing and ensures that the exhaust gas is diverted through the treatment element.

[0063]It should be recognized that the gasket 316 is described above by way of example only. Of course, other configurations of the gasket that are particularly adapted to inhibit the flow of gas in the space formed by adjacent walls while simultaneously permitting an exchange of thermal energy

between the gas and at least one of the walls are considered within the scope of this disclosure.

[0064] Yet another exemplary embodiment of the device 410 is illustrated in Figure 11. Here, the device 410 manages the expansion of the housing 412 with respect to that of the treatment element 414 to minimize changes to the space 420 through the selection of materials of the housing.

[0065] In this embodiment, the housing is formed from austenitic steel such as, but not limited to, SAE 304 (Society of Automotive Engineers 304) stainless steel. Austenitic steels have a coefficient of thermal expansion of about 18×10^{-6} cm per degree C or higher in the operating temperature range of the device. Thus by using an austenitic steel having a higher coefficient of thermal expansion than previous ferritic housings, the housing expands more rapidly with respect to the expansion of the treatment element (e.g., 4×10^{-6} cm per degree C) even though the housing is exposed to a lower temperature than the treatment element. Thus, the selection of materials for housing 412 mitigates, reduces, and/or eliminates the change in the space 420. Accordingly, the device 410 reduces damage to the gasket 416 and/or to the treatment element 414 and enables the use of the less expensive commercially available intumescent gaskets 416 by providing reduced frequency of substrate failure and less wear on the gasket in use.

[0066] The devices are described above separately for the purposes of clarity only. Of course, the use of these devices alone and/or in combination with one another is contemplated.

[0067] The selection of one or more of the previous methods depends on the temperatures for which the device is designed. These temperatures are affected by many factors but in particular by the calibration of the vehicle. The calibration of a trap regeneration cycle may allow only short periods for soot accumulation between regenerations. This would produce only a mild elevation in trap temperatures from the exothermic reaction of the burning soot. In this case the application of only one embodiment may suffice.

[0068] On the other hand if a large amount of soot is allowed to accumulate in the trap prior to regeneration, very high regeneration

temperatures will occur. If very high trap substrate temperatures occur several of the embodiments might have to be applied.

[0069] The temperature of the trap during periodic burning of the soot (regeneration) can far exceed the inlet temperature. Under these conditions it would be best to maximize housing expansion by heating the housing from the outlet end of the substrate, since the inlet end may well be cool from a "low power" operating condition of the engine. At other times, when the trap is not being burned out, it will be best to heat the housing from the inlet side of the substrate, since the inlet gases will at times be at a higher temperature than the substrate or outlet gases. It is under these diverse conditions that it may be necessary to use one embodiment for the inlet side, and another embodiment for the outlet side, the result will be a heating of the housing to a temperature somewhere between the temperature of the inlet and outlet gases.

[0070] While the invention has been described with reference to an exemplary embodiment, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the appended claims.